

REPORT OF AFB/ $\sin^2\theta_W$ /ANGULAR WORKING GROUP

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SMP-V MEETING / APR. 19TH, 2012

GROUP ORGANIZATION

- This group is organized for
 - 2012 data analysis / publication of A_{fb} , $\sin^2\theta_W$, angular coefficients
- The group consists of
 - Joint Inst. for Nuclear Research (Dubna)
: Sergei Shmatov, Alexander Lanyov, Ilya Gorbunov
 - Texas Tech University (TTU)
: Nural Akchurin, Sung-Won Lee, Cosmin Dragoin, Keng Kovitanggoon, John Sandy
 - University of Rochester
: Arie Bodek, Jiyeon Han
 - Purdue University
: Matthew Jones, David Silvers
 - Johns Hopkins University /FNAL
: Andrei Gritsan, Nhan V Tran
- The meeting will be bi-weekly (2nd and 4th week) at 4:00 PM (CERN)
- The kick-off meeting was held last Wed (Apr. 11th)
 - Discussion of group's participation/status/plan
 - More details are at <https://indico.cern.ch/conferenceDisplay.py?confId=185905>

PARTICIPANTS' INTEREST

- Group's interest on each topic (Man-power)

A_{fb} :

muon channel \Rightarrow

TTU (2S, 1P, 1UG)

Dubna (1S, 1P, 1G)

electron channel \Rightarrow

TTU

$\sin^2\theta_w$:

muon channel \Rightarrow

Dubna

Johns Hopkins (1S)

FNAL (1P)

electron channel \Rightarrow

Possible contribution by

Dubna

Angular coefficients :

muon channel \Rightarrow

Rochester (1S, 1P)

Purdue (1S, 1G)

electron channel \Rightarrow

Possible contribution by

Rochester

Purdue

S : scientist/professor

P : postdoc

G : PhD student

UG : undergraduate

- Muon channel is more prior than the electron channel
- The analysis can be extended for the electron channel

OVERALL ANALYSIS PLAN

- The analysis will be performed using 2012 data
 - Some of methods are already used for 2011 data publication
 - New approaches are developing using 2011 data
 - Time scale of the analysis :
 - Get approval targeting winter conference (Moriond 2013)
 - Pursue the publication after the approval
 - Not determined how many publication will go (1, 2, or 3 ??)
 - Prefer to separate the angular measurement from $A_{fb}/\sin^2\theta_W$
 - $A_{fb}/\sin^2\theta_W$: EW vs. angular coefficients : QCD physics
- Share the common effort to speed up the analysis
 - Data skimming, efficiencies, background estimation... so on
 - More detailed discussion will be continued in the group

AFB/ $\sin^2\theta_W$ MEASUREMENT AT 2011

■ Afb measurement

- Full 2011 data is used (4.7 fb^{-1})
- Afb is measured as a function of mass and rapidity (4 y bins)
- Event counting method is used
- μ and e channel is combined for the final result
- Approved on Feb. 03, 2012
- On the way of publication (Ready for CWR)

■ $\sin^2\theta_W$ measurement

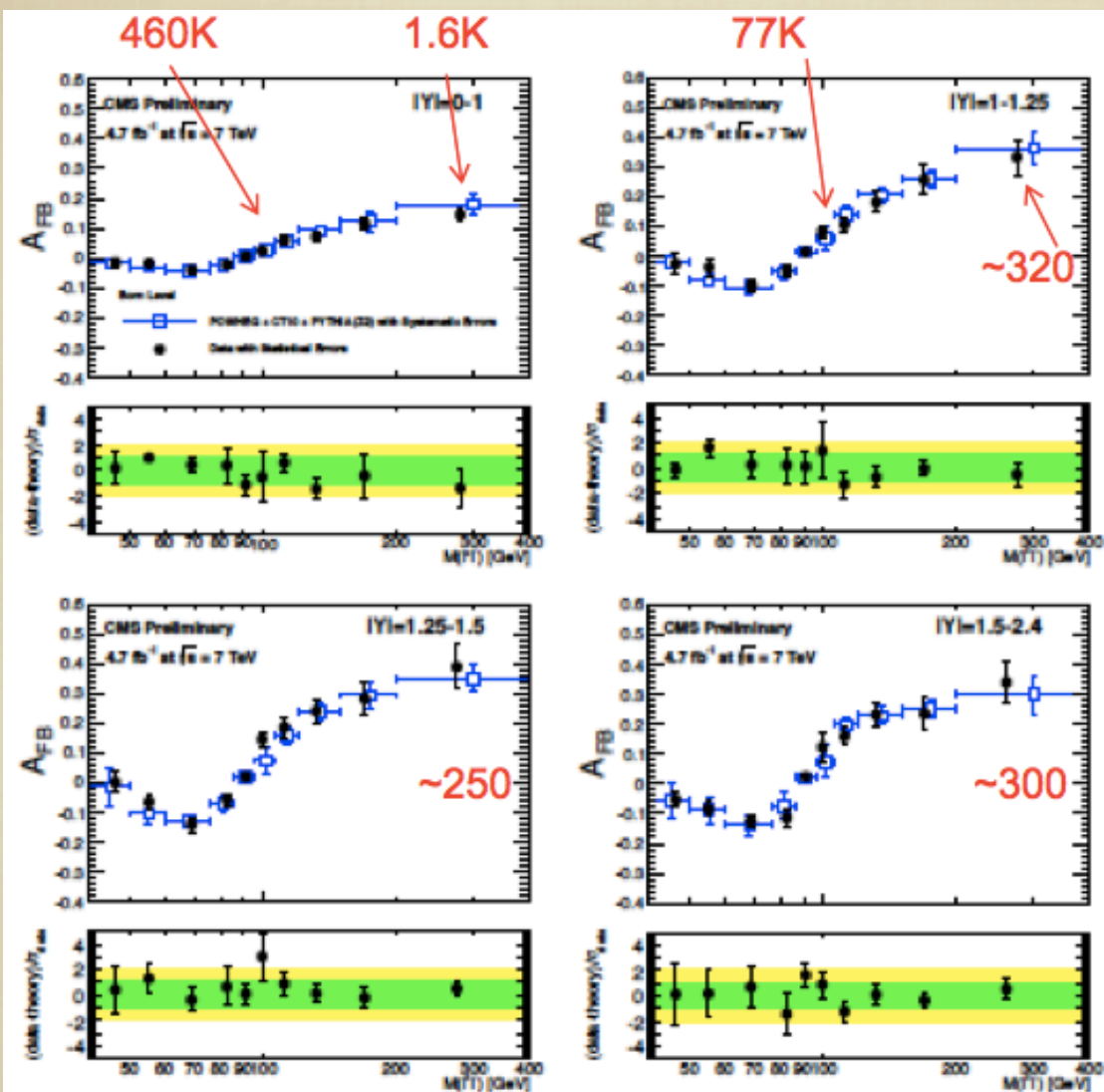
- 1.1 fb^{-1} data is used to extract $\sin^2\theta_W$: only μ channel considered
- The multivariate likelihood function is used to extract maximal info.
 - Kinematic distributions (M, $\cos\theta$, y) are used
- The measurement was published last year : PRD 84 (2011) 112002

AFB/ $\sin^2\theta_W$ MEASUREMENT AT 2012

- TTU will continue Afb for both μ and e channel using 2011 method
 - The forward electron (HF) will be included to cover higher rapidity
 - New postdoc, Cosmin Dragoiu, will inherit (Efe and Youn)'s tool
- Dubna will measure $\sin^2\theta_W$ using 2011 method and develop Afb method
 - Ilya presented the status of Afb/ $\sin^2\theta_W$ work at last SMP-V meeting
 - Right now, only muon channel is used for the analysis
 - Afb measurement :
 - Develop the $\cos\theta$ fitting method
 - The counting method (2011 method) is also used for cross-check
 - $\sin^2\theta_W$ measurement :
 - 2011 method is used to extract $\sin^2\theta_W$
 - Andrei/Nhan will contribute on systematic study
 - PDFs, FSR, LO model, alignment are leading systematics

AFB PROSPECT BASED ON 2011 DATA

- From Nural's slide at the kick-off meeting



8 TeV provides gain in rate and mass reach, probably $\sim 1.3x$ around Z pole and $\sim 1.5x$ ~ 1 TeV

Number of electron events is indicated on the plots at the Z pole and in the highest mass bin (200-2000 GeV) in 2011 data

Total number of electron events is 0.9M whereas the total for muons is 1.9M

High mass region will be more interesting at 2012 !!

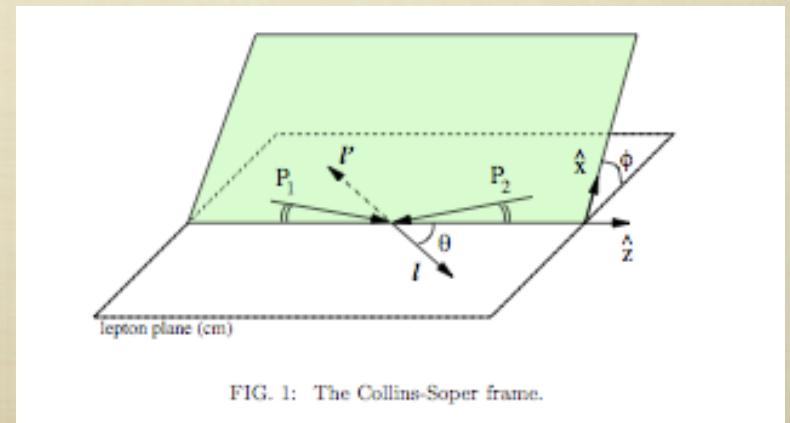
ANGULAR COEFFICIENTS

- Angular measurement has not been presented at physics group yet
- Rochester and Purdue group will preform the measurement
- μ channel is more priority and then e channel will be considered

$$\begin{aligned}
 \frac{d\sigma}{dP_T^2 dy d\cos\theta d\phi} \propto & \boxed{(1 + \cos^2 \theta)} \xrightarrow{\text{green}} \boxed{\text{LO term}} \\
 & + \frac{1}{2} A_0 (1 - 3 \cos^2 \theta) \xrightarrow{\text{blue}} \text{cos}^2\theta : \text{higher order term} \\
 & + A_1 \sin 2\theta \cos \phi + \frac{1}{2} A_2 \sin^2 \theta \cos 2\phi + A_3 \sin \theta \cos \phi \rightarrow (\theta, \phi) \text{ terms} \\
 & + \boxed{A_4 \cos \theta} \xrightarrow{\text{green}} \boxed{\text{LO term : determine } A_{fb}} \\
 & + A_5 \sin^2 \theta \sin 2\phi + A_6 \sin 2\theta \sin \phi + A_7 \sin \theta \sin \phi \rightarrow \text{very small terms}
 \end{aligned}$$

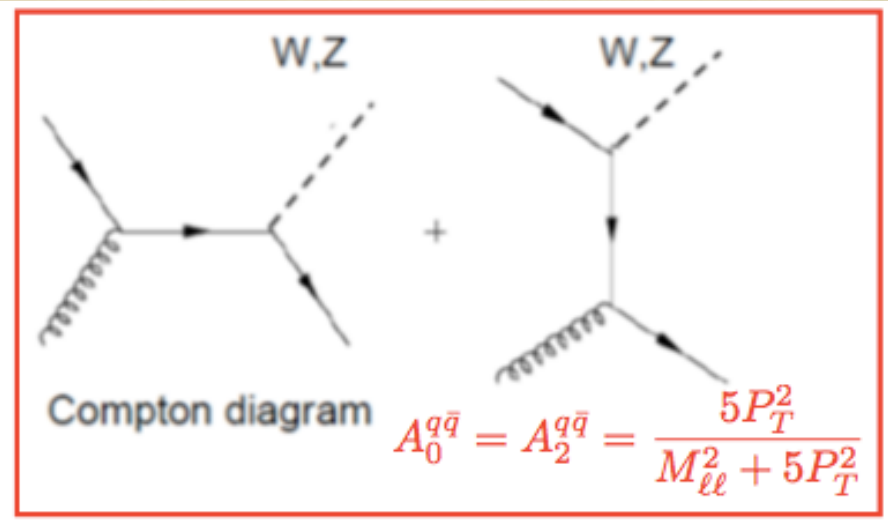
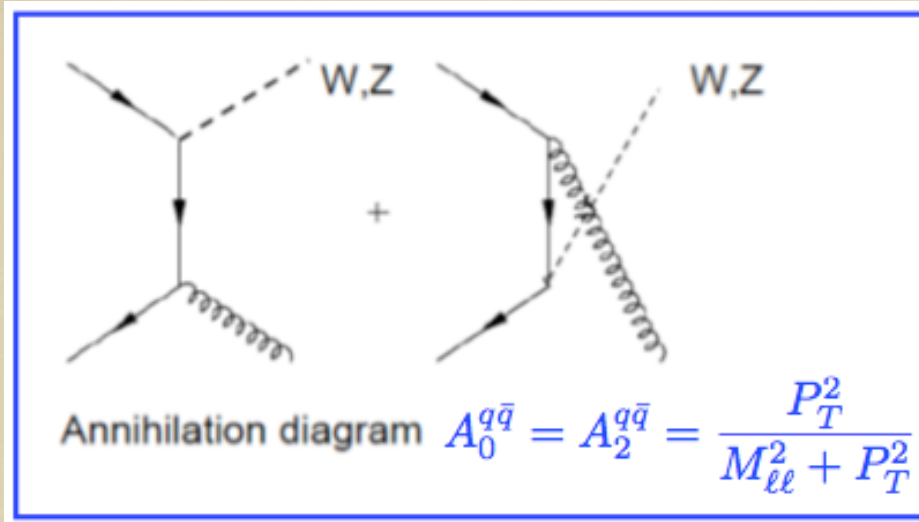
- pQCD makes definite predictions for angular coefficients, $A_{0,2,3,4}$

- $A_{0,2}$ are the same for γ^*/Z exchange
- $A_{3,4}$ originate from γ^*/Z interference
- A_4 has a direct relation with A_{fb} which is sensitive to $\sin^2\theta_W$, (g_V, g_A coupling)



ANGULAR COEFFICIENTS IN NLO

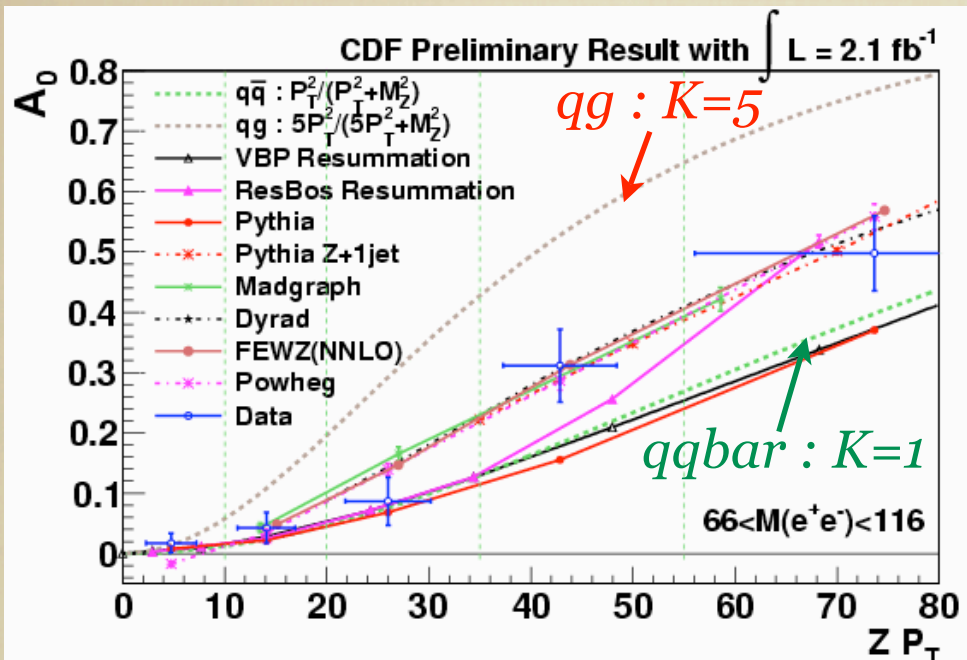
- Drell-Yan process in NLO : Process has a finite boson P_T



- The angular distribution (A_0, A_2 in P_T) is different for two processes
- The angular coefficients measurement in P_T provide a detailed test of the production mechanism of gauge boson
- Standard model QCD in all order predicts $A_0=A_2$: **Lam-Tung relation**
 - Lam-Tung relation is only valid for vector gluons (spin 1)
- The contribution of Compton process is expected to be larger at LHC
 - Comparison b/w LHC vs. Tevatron will be interesting

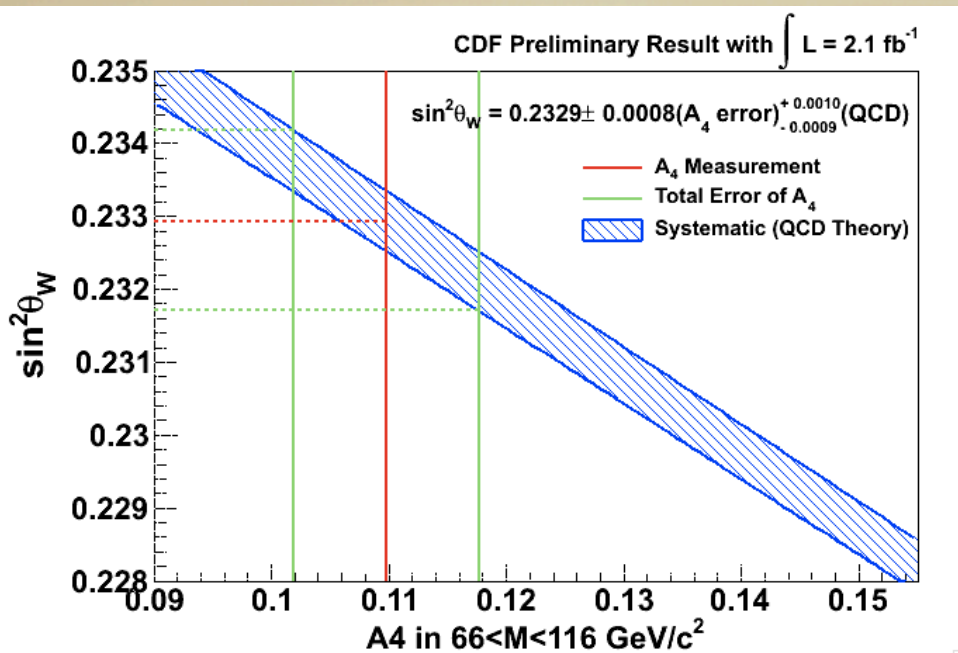
ANALYSIS APPROACH: ROCHESTER

- Angular coefficients in P_T was published at CDF : [PRL 106, 241801 \(2011\)](#)



- Coefficients are measured in Z mass region
- Data prefers higher order prediction
- $$A_0 = A_2 = \frac{K \times P_T^2}{M_{\ell\ell}^2 + K \times P_T^2} \Rightarrow K = 1.65$$
- $K=1$ for qqbar vs. $K=5$ for qq
- Confirmed Lam-Tung relation

- Maximum log-likelihood fitting method is used
 - $A_{0,4}$ are extracted by fitting $\cos\theta_{CS}$, and $A_{2,3}$ by fitting ϕ_{CS}
- Same technique is applied to CMS
 - Analysis tool is ready and applied to 2010/2011 data
 - $\cos\theta_{CS}$ and ϕ_{CS} is sensitive to muon momentum correction
 - Developing muon momentum correction : [AN/2012/062](#)



$$A_4 = \frac{8}{3} A_{fb}(M_{\ell\ell}, P_T, y)$$

- $\sin^2\theta_W$ vs. A_4 averaging over Z mass
- $\sin^2\theta_W$ is extracted using various generator programs
- The fixed $\sin^2\theta_W$ at Z pole is used for all Q^2 in generator
- Systematics from QED is not included

- A_4 measurement averaging Z mass region can confirm A_{fb} result
 - $\sin^2\theta_W$ extracted from A_4 provides a cross-check of $\sin^2\theta_W$ measured by A_{fb} or log-likelihood fitting method (Nhan's method)

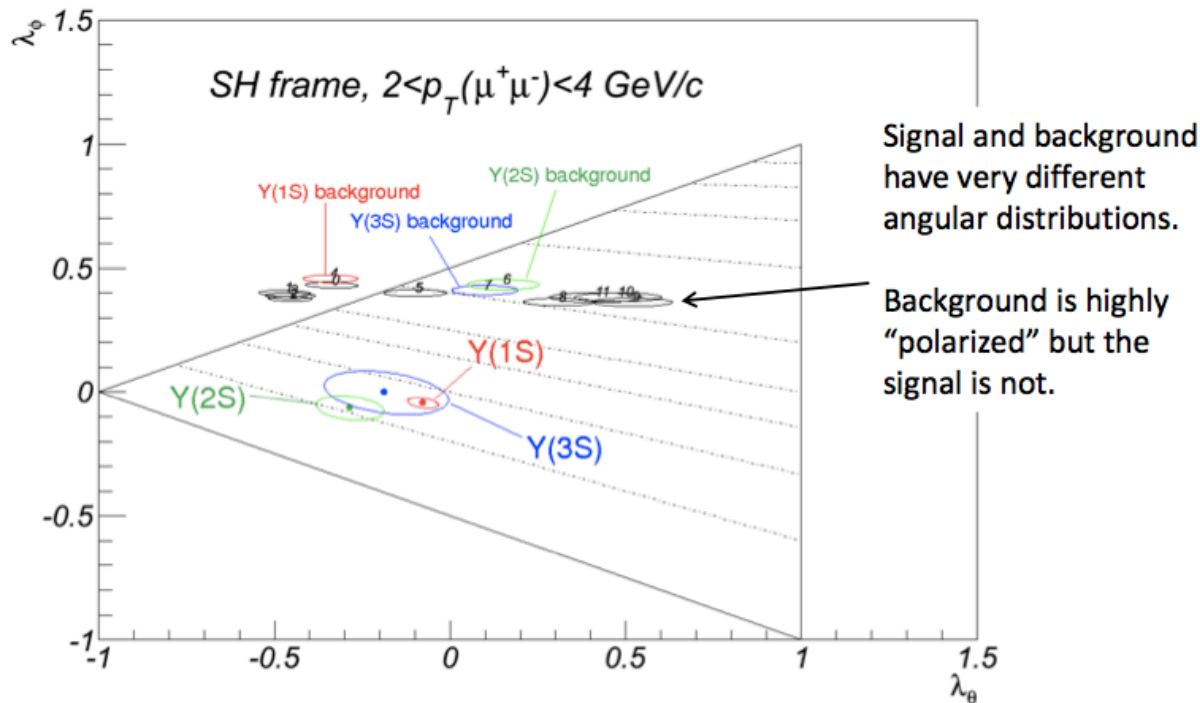
ANALYSIS APPROACH: PURDUE

- Publishing CDF $Y(nS) \rightarrow \mu^+\mu^-$ polarization analysis at CDF : [arXiv:1112.1591](https://arxiv.org/abs/1112.1591)
- Slightly different approach from Rochester's method
- Factorize A, ε , underlying angular distribution for signal + background

$$\frac{dN_p}{d\Omega_{ij}} \sim N_Y f_p \mathcal{A}_Y(\cos \theta_i, \varphi_j) \cdot w_Y(\cos \theta_i, \varphi_j; \vec{\lambda}_Y) + N_{ds} f_p \mathcal{A}_b(\cos \theta_i, \varphi_j) \cdot w_b(\cos \theta_i, \varphi_j; \vec{\lambda}_b),$$

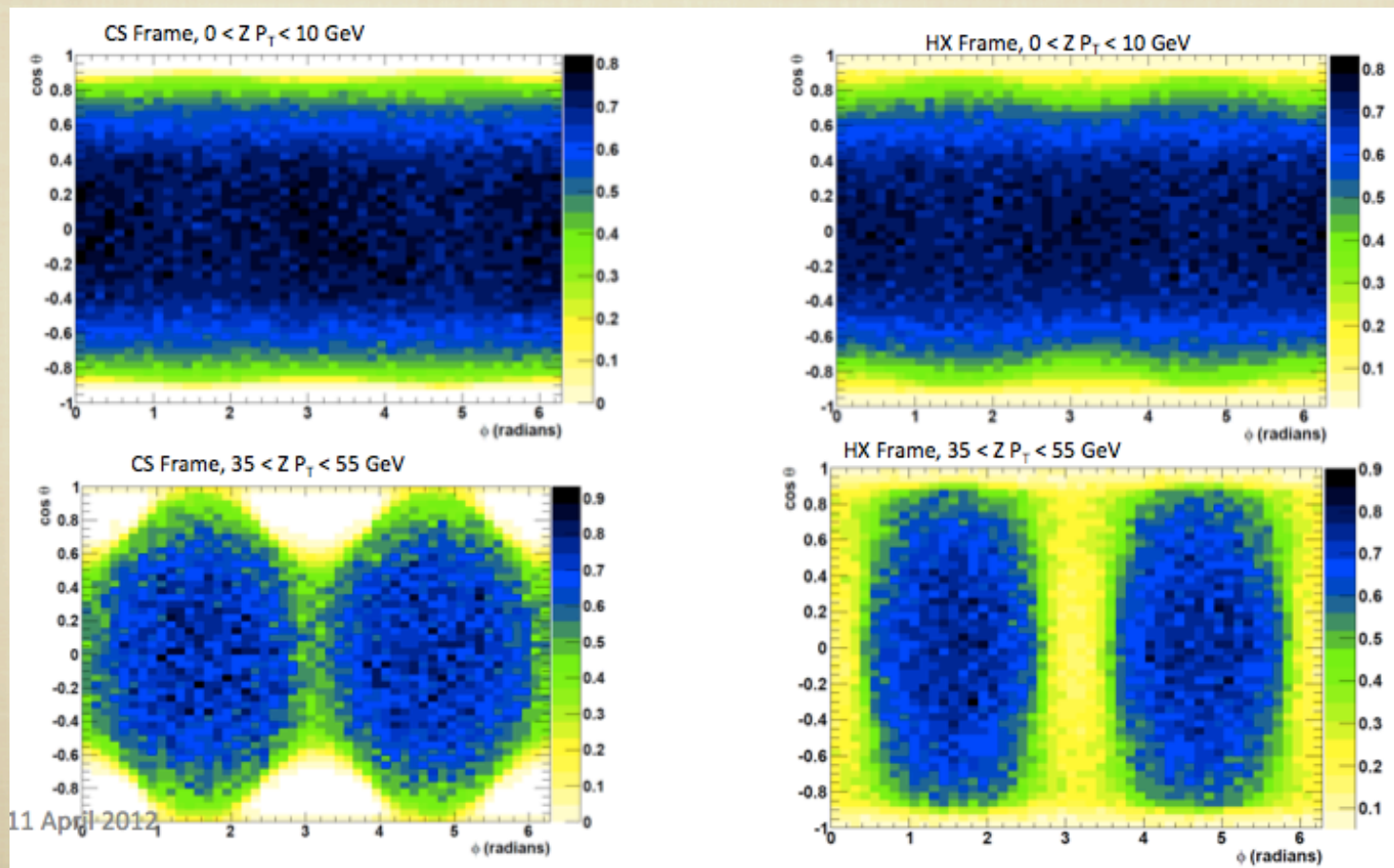
$$\frac{dN}{d\Omega} \sim 1 + \lambda_\theta \cos^2 \theta + \lambda_\varphi \sin^2 \theta \cos 2\varphi + \lambda_{\theta\varphi} \sin 2\theta \cos \varphi,$$

- Parameter correlation is incorporated
- Acceptance depends on P_T and $M(\mu\mu)$



- CDF result with 6.7 fb^{-1}
- Fitting returns the parameters for both signal and background

- Application to CMS $Z \rightarrow \mu^+ \mu^-$ data using 2011 Drell–Yan selection
 - Acceptance calculation using MC with trigger efficiency
 - Calculated separately in each $Z P_T$ range analyzed
 - Efficiency is estimated and compared with the result of Drell–Yan group
 - Fit angular coefficients using S+B model
- Parameterizing angular coefficients in $M(\mu\mu)$ accounts for FSR, γ^*/Z interference



SUMMARY

- The working group started working to pursue 2012 data analysis
 - Many of analysis already improved the analysis technique and tools
 - The analysis tools are applied to 2011 data
 - Validating and cross check the tools
 - More discussion will be continued in the meeting for
 - how to manage the common efforts
 - develop the analysis approach for the publication
 - analysis details ...
- The regular meeting will be at Monday, 4:00 PM (CERN) (2nd, 4th week)